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IMPACT OF CHANNEL OPTIONS ON REPEATER DESIGN

INTRODUCTION

This note presents an analysis of various techniques proposed for the channelization of the packet radio network. The channelization methods considered do not include all possible, but represent a cross-section of many of the ideas of the group. The criteria of analysis is equipment complexity. The channelization schemes considered are as follows:

A. Narrow band single channel
B. Narrow band selective single channel
C. Narrow band dual adaptive selective channels
D. Code spread spectrum single channel
E. Code spread spectrum selective single channel
F. Code spread dual adaptive selective channels
G. Code spread spectrum with dual data rates
H. N-parallel code spread spectrum channels

Several assumptions are made in the evaluation of the candidate channelization schemes. These assumptions are:

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1. Radio channel will be somewhere in the 1 GHz to 2 GHz range with approximately 150 MHz available bandwidth.
2. The modulation will be minimum shift keying (MSK).
3. Minimum data rate of the order of 100 KB/S
4. Target bit error probability of 10^{-5}.

Candidate Descriptions

A. The narrowband single channel is a fixed 150 KHz BW channel that the entire network would operate on. This represents the simplest approach to the question of channelization.

B. The narrow band selective single channel is identical to the narrow band approach with the additional flexibility of being able to choose the center frequency of the channel. This selection would be based on apriori information regarding the spectral environment with which groups of network elements must coexist.

C. Narrow band dual selective channels is a channelization method whereby a network element can adaptively choose the narrow band channel it will use for transmission and reception based on the traffic level and presence of non-network spectrum users. The repeater network element handles repeater-repeater traffic and terminal-repeater traffic simultaneously. A new channel selection would take place whenever the packet transmission time delays or number of retransmissions become excessive or when a non-network user causes coexistence problems.

D. Code spread spectrum single channel spreads the 150 KHz channel by a factor of the order of 100 to reduce the spectral density of the transmitted signal. This results in a channel of 15 MHz bandwidth. The spectral density of 1/100 of the narrow band case for a given transmitter power.

E. The code spread spectrum selective single channel is identical to D with the additional flexibility of selecting the center frequency of the channel based on apriori information about the spectral environment of the network element.

F. The Code Spread Dual Adaptive selective channel scheme provides for adaptively changing a spread spectrum frequency channel to avoid traffic delays or coexistence problems. The approach is similar to scheme C which was for narrow band channels. The terminal to repeater frequency is adaptively selected independent of the repeater to repeater frequency selection and both channels operate simultaneously.

G. Code spread spectrum with dual data rates is similar to E; however, a higher data rate is used for repeater-repeater traffic than for terminal-repeater traffic. The repeater-repeater link data rate would be of the order of 500 KB/S obtained by maintaining the 10M chip rate but reducing the number chips per bit. This would take advantage of the difference in the characteristics of the media between repeater-terminal mobile links which are subject to higher path loss, multi-path and impulsive noise and repeater-repeater links which should approach free space path loss and known multi-path. This difference could be as much as 40 db in path loss of equal spaced links.

H. The N-parallel code spread spectrum is a channelization technique where a network element can select N-parallel channels from an ensemble of channels within a 150 MHz band to operate on simultaneously. This allows for (1) greater traffic volumes between lower path-loss links, such as repeater-to-repeater, (2) selection of channels that do not have coexistence problems and (3) redundancy (greater spread) in message transmission for designated critical traffic.

Equipment Complexity

This section discusses equipment implementation and the relative complexities for each channelization scheme considered in this note. Table 1 shows features of the transmitter and receiver excluding microprocessor and interface functions.

The appendix contains block diagrams pertinent to this discussion. Figure 1 is a general block diagram applicable to all channelization schemes.

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Figure 2 depicts the recommended method of MSK modulation using SAWD's as impulsed match filters of 2 chip (bit for NB cases) length. This method is chosen over an impulse "coded SAWD" since more energy can be impulsed into the matched filter. The third column of the chart shows the length of SAWD required and the fourth column is the required IF. Higher IF's are required for adaptive channel schemes.

Figure 3 depicts the RF head portion of the packet radio for all channelization schemes. The difference between schemes is the bandwidth of the output bandpass filter, which is limited to $\geq$2% BW due to filter limitations for NB cases and 140 MHz BW for WB cases.

The transmitter/receive LO are assumed to be identical frequencies. Two different schemes are envisioned, one for fixed frequency single channel operation; the other for a frequency agility that is implemented by a digital frequency synthesizer. These are shown in Figures 4 and 5 respectively.

The IF, signal detection, bit synchronization and pre-amble detection circuits are all shown in Figure 6. The AGC amplifier requirements, signal detection (following SAWD's), bit sync and pre-amble are essentially the same for all channelization schemes considered. As noted on the diagram, the SAWD's and SAWD implementation is dependent on channelization and, of course, dependent on modulation type.

Following is a discussion of equipment implementation for each channelization option.

A. Narrow Band Single Channel

This traditional channelization scheme is the simplest to design and implement. No code generator in the modulator is required. Standard 70 MHz IF's are chosen to use currently available circuits. Only hardware problem is implementation of 150 KHz bandwidth filter at 70 MHz. This is a 0.2% bandwidth. An LC filter cannot be

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built to meet this requirement, but a crystal filter can be designed to meet this requirement without too much difficulty.

B. Narrow Band Selective Channel

Since a frequency agile system is required, a synthesizer with 1 MHz steps would have to be designed. Antenna and output filter must have 140 MHz bandwidth to permit frequency channeling. The IF must be in the region of 200 MHz, since the IF should be somewhat higher than RF bandwidth to preclude spurious emission in the antenna. Because of the narrow bandwidth (0.1%) at 200 MHz, LC filters are not practical and crysta filters are not feasible, a second IF (such as 10.7 MHz) is required to realize this bandwidth requirement.

C. Narrow Band Dual Adpative Selective Channel

The requirements for this channelization scheme are the same as B, the NB selective channel set-up, plus additional isolation requirements. Single universal modules are required for terminals where one frequency is dynamically allocated. For repeaters, two modules are assumed. This essentially creates full duplex operation with repeater/terminal traffic on one channel and repeater/repeater traffic on another channel. Since these two modules are physically close together, a high degree of isolation is required from one transmitter to the adjacent receiver. If the antennas are 5 feet apart, then there would be only 40 db of propagation loss. This means that with 10 dbi of antenna gain on both transmit and receive antennas and the transmitter P.A. output of 40 dbm, then the input to the receiver preamp would be 100 MW with no filtering. For this reason, a very narrowband tunable (for adaptive selective channelization) filter is required. There are no tunable filters such as Yig filters which have 150 KHz bandwidth. The antennas might be arranged in such a way that additional isolation is obtained. For example, vertical polarized antennas could be

stacked to provide additional isolation. However, this channelization method has no reasonable solution to full duplex operation.

D. Code Spread (WB) Single Channel

This scheme is similar to scheme A (NB single channel) except spread spectrum using code spreading techniques is used.

A code generator must be used. This code generator uses conventional TTL, and must generate one of two codes dependent on the data bit value. A 20 MHz bandwidth filter is required, both at the RF in/output and at the IF. Unlike the NB case, a crystal filter design is not necessary. The receiver requires 100 chip coded SAWD matched filters.

E. Code Spread (WB) Selective Channel

The technique combines the features of B and D, NB selective channel and WB spread spectrum. Therefore, equipment complexities are commensurate; i.e., a wider RF bandwidth (140 MHz), a higher IF, coded SAWD's and a synthesizer are required. These particular requirements have been discussed in earlier sections.

F. Code Spread (WB) Dual Adaptive Selective Channels

This system embodies C and D configurations; i.e., selective, frequency adaptive channelizations with spread spectrum.

This channelization concept essentially requires all of the additional equipment circuitry discussed in all the previous sections; i.e., code generators, RF and IF bandwidths, coded detection SAWD's, synthesizers and isolation. The problem of isolation for full duplex operation can be solved with Yig filters, since the bandwidth is 100 times wider for the spread over the non-spread. However, these filters will require continuous power for tuning and heating (temperature compensation) of the order of 15 watts for the two filters. In addition, there will be as much as 5 db of insertion loss through the filter.

G. Code Spread Dual Rate Selective Channel

This channelization procedure is identical to E, except that dual rates (100 & 500 KBPS) are used. Spectrum occupancy and spectral density is identical in both rates since the chip rate (10 MCPS) is assumed constant and the spread factor Nc chips per bit reduced. If higher rates are assumed for repeater/repeater operation only, and since this operation is more than likely line-of-sight, higher SNR result and can sustain higher data rates without degradation.

Compared to E, WB Selective channeling, this technique would allow the same MSK modulator code generator to generate four codes (two at each rate) instead of two. This is the only transmitter circuitry over scheme E that is required, except for possible interface modification with the microprocessor.

The receiver would remain unchanged from that of receiver E up to the SAWD's. Here, two more SAWD's would be required at the higher rate. The remaining IF and signal processing circuitry would be duplicated, the second to handle the higher rate. This would include signal detection, pre-amble detection and AGC. If sample and hold type of phase detection (harmonic mode phase detection) is used in the bit synchronization circuitry, then the bit sync circuitry need not be reproduced.

H. N-Parallel Code Spread Channels

The channelization techniques would essentially be N modulators with 2 watt PA's with a common power combiner to the antenna where each modulator would be of the code spread type. Similarly, the receiver would use a common pre-amp followed by a power divider feeding essentially N independent down converters, IF's and demodulator circuits.

Special techniques could be used in the frequency generation circuit to generate N local oscillators to simplifying hardware requirements. Considering a linear power amplifier for the common amplification of these N channels, it should be noted that the peak power capability of the amplifier must be N^2 times the peak power of any one channel. This seriously limits the signal power for a given channel and reduces the range of operation. For example, a 10 watt peak power amplifier with five channels could handle only 400 MW on each channel for full linear operation. The efficiency of this P.A. would be approximately one-fourth that of a class C P.A.

CONCLUSION

A summary of the previous sections is shown in the following table for equipment complexity.

A rating of 1 to 8 is used, 1 being most desireable or least equipment complexity. This rating is not in absolute terms, but only in relative terms or qualitative levels; i.e., a 2 rating has more equipment complexity than a 1 rating, but how much more complex is not implied.

TABLE OF CHANNELIZATION OPTIONS CRITERIA COMPARISONS

	EQUIPMENT COMPLEXITY
A. Narrowband Single Channel	(1)
B. Narrowband Selective Channel	(3)
C. Narrowband Dual Selective Channels	(8)
D. Code Spread Single Channel	(2)
E. Code Spread Selective Channel	(4)
F. Code Spread Dual Adaptive Selective Channels	(7)
G. Code Spread Dual Data Rates Selective Channel	(5)
H. N-Parallel Code Spread	(6)

( ) Ratings to 8 - 1 being least complex
8 being most complex

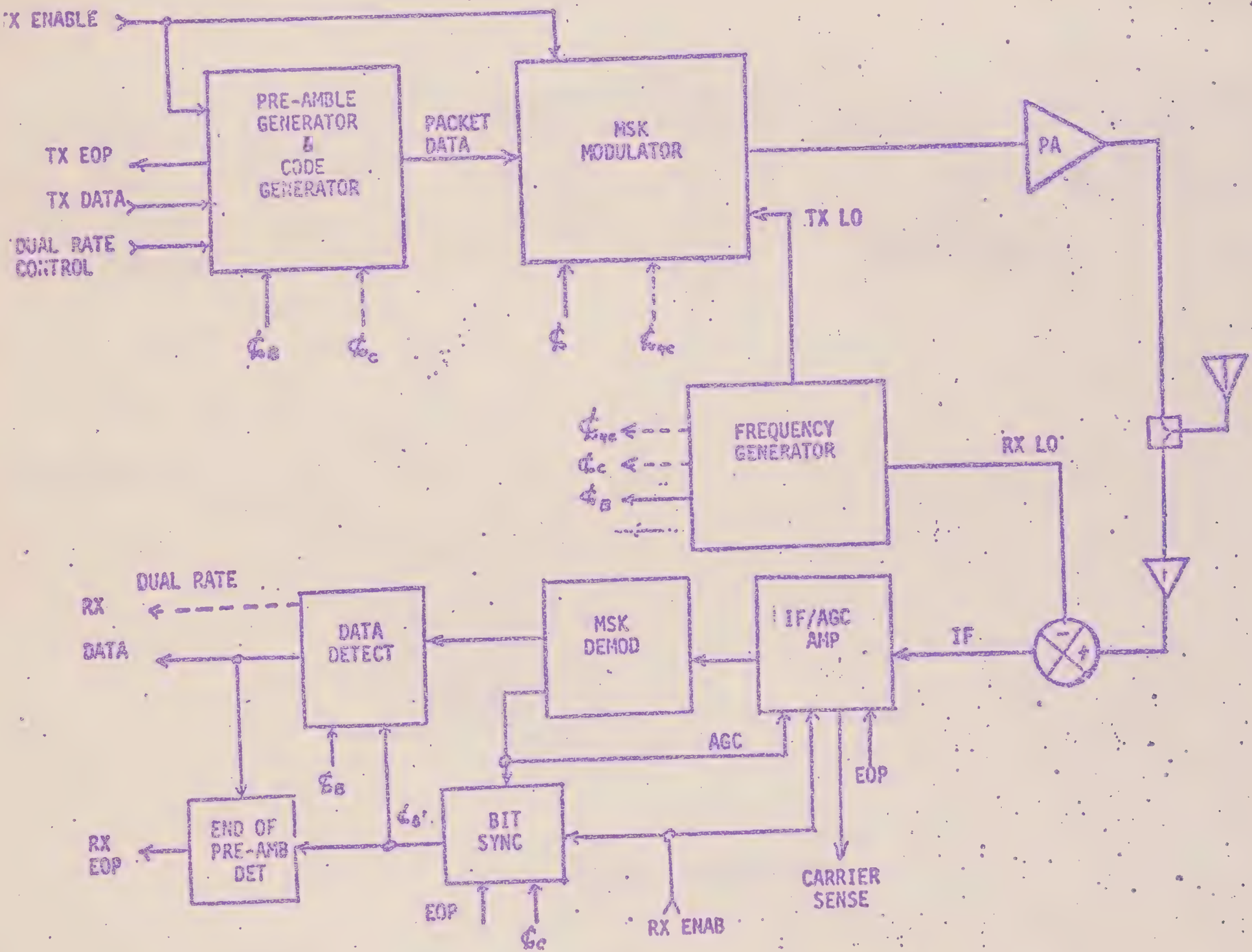


FIGURE 1: BLOCK DIAGRAM

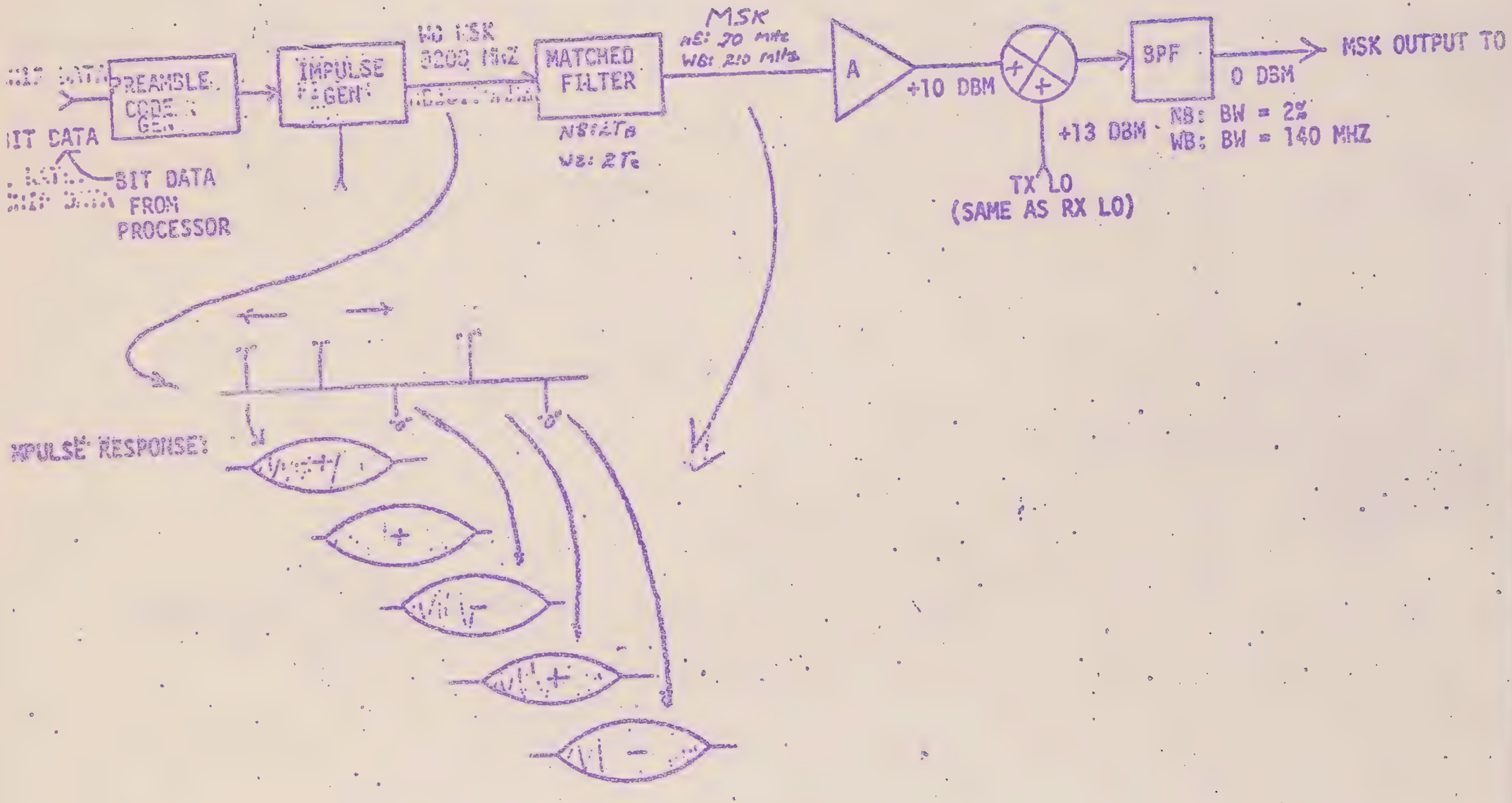


FIGURE 2: MSK MODULATOR

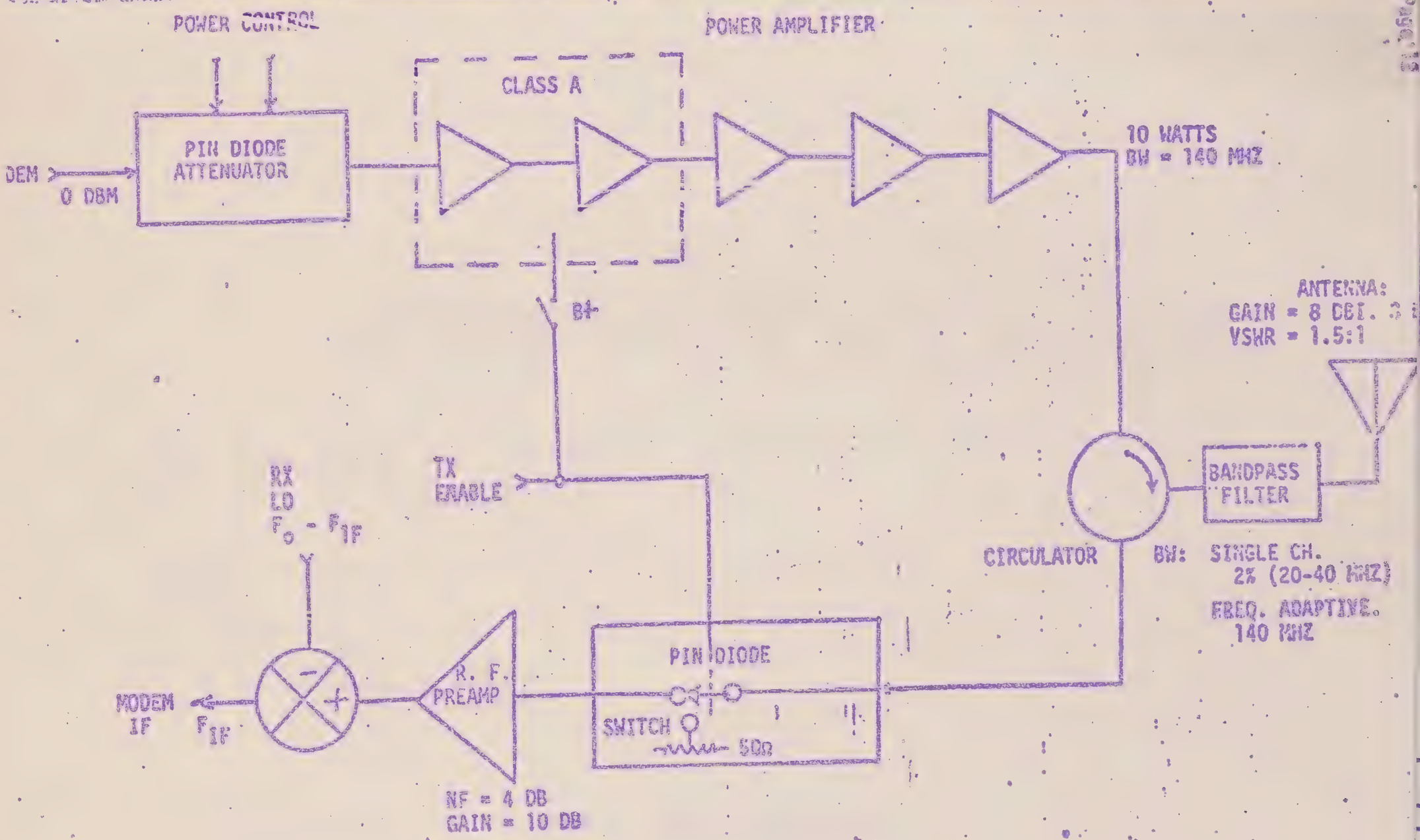


FIGURE 3: R.F. SYSTEM

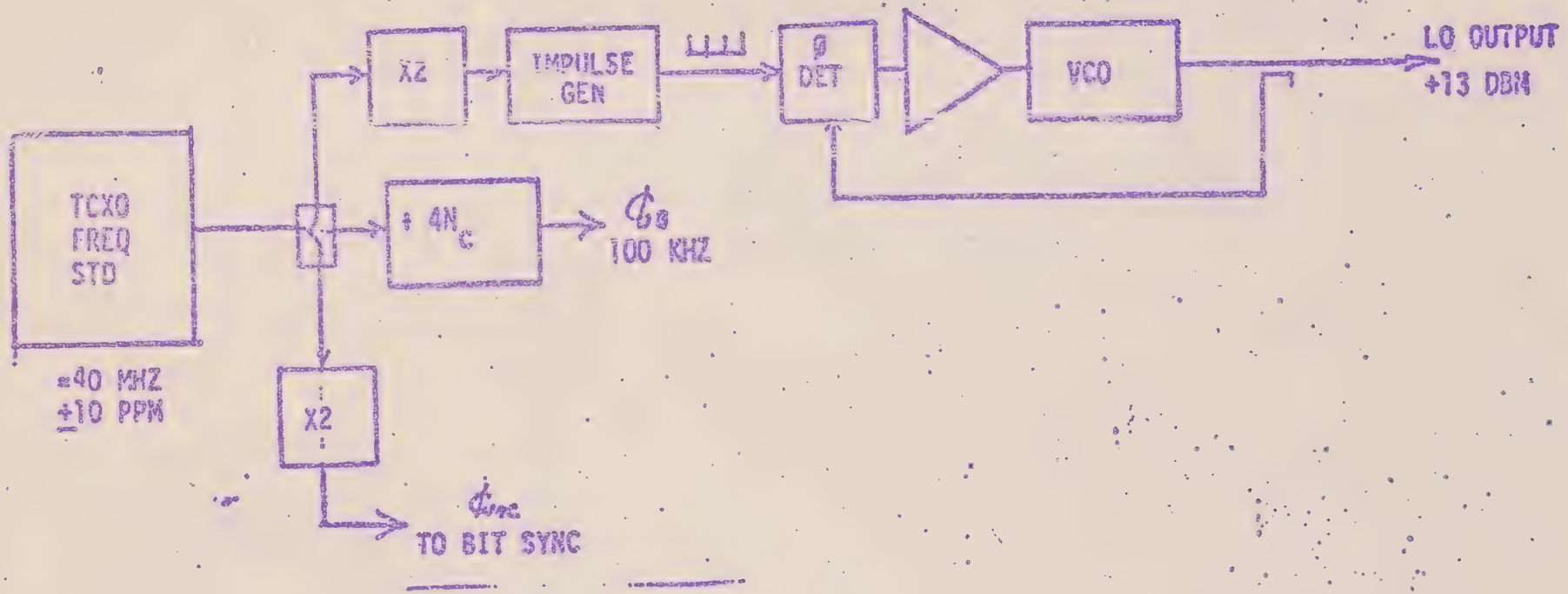


FIGURE 4: FREQUENCY GENERATION
NB & WB SINGLE CHANNEL

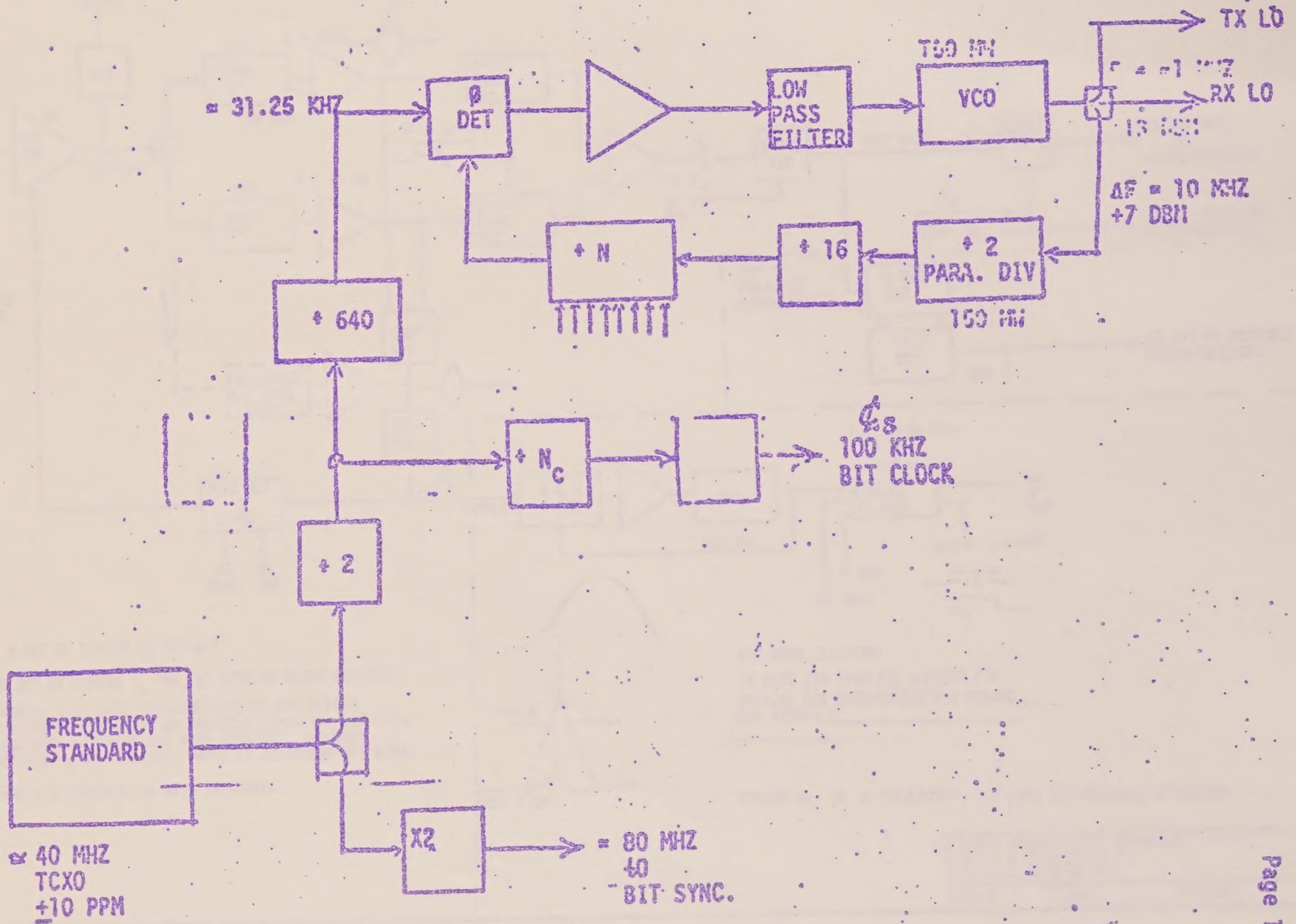
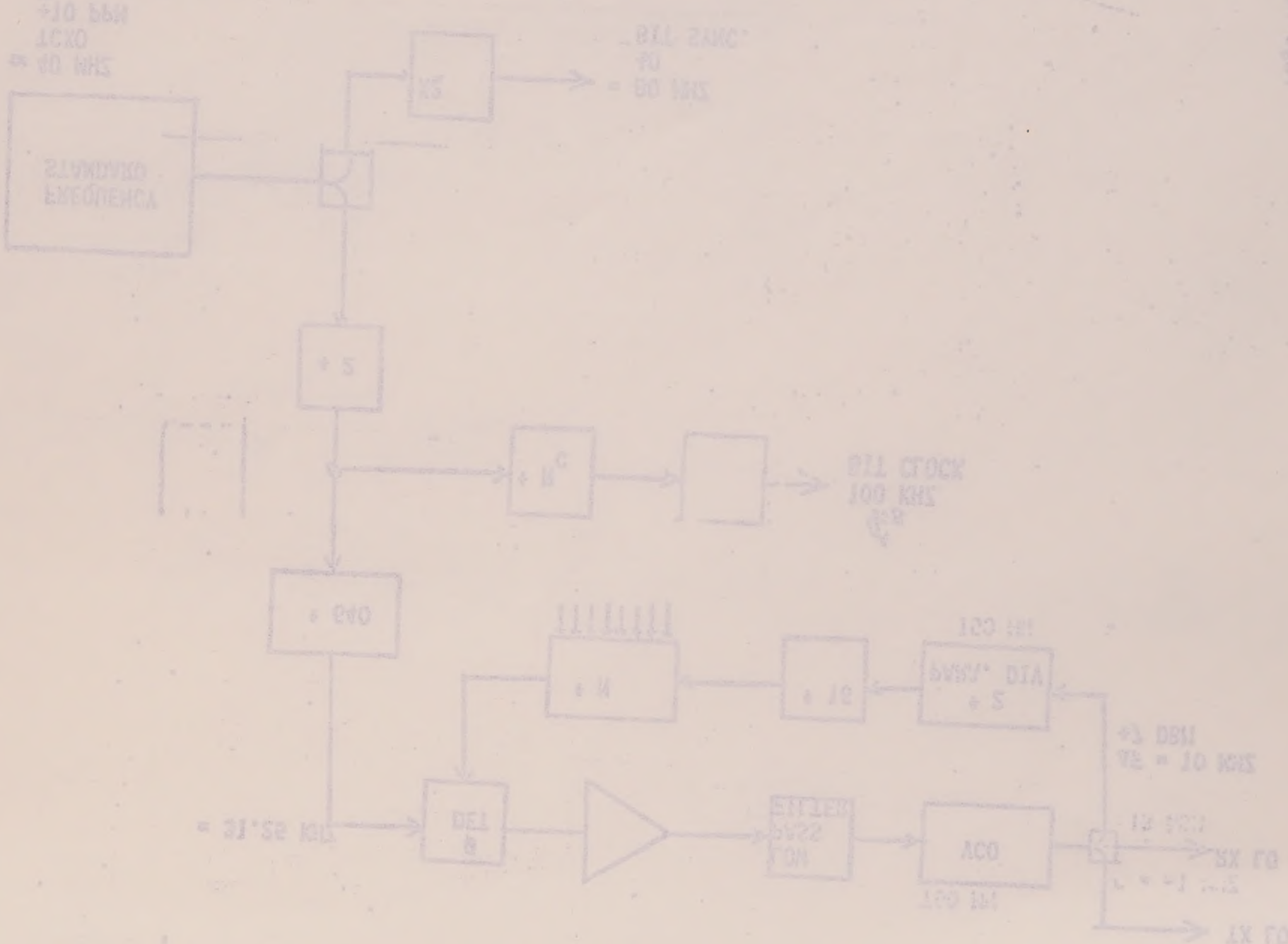


FIGURE 5: FREQUENCY SYNTHESIZER, 1 MHZ STEPS
NB & WB FREQUENCY ADAPTIVE CHANNELS AND
DUAL RATE
PARALLEL SPREAD



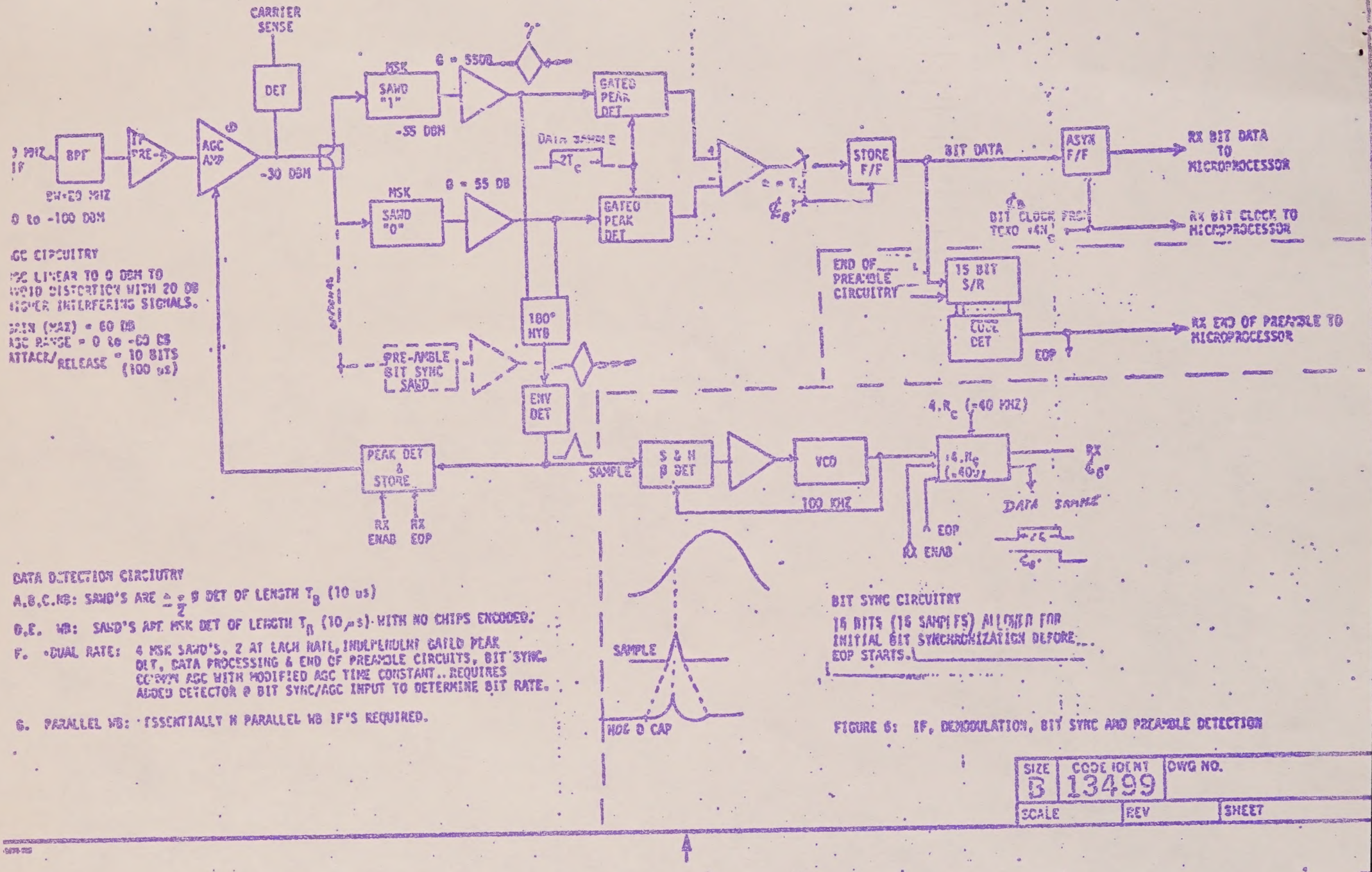
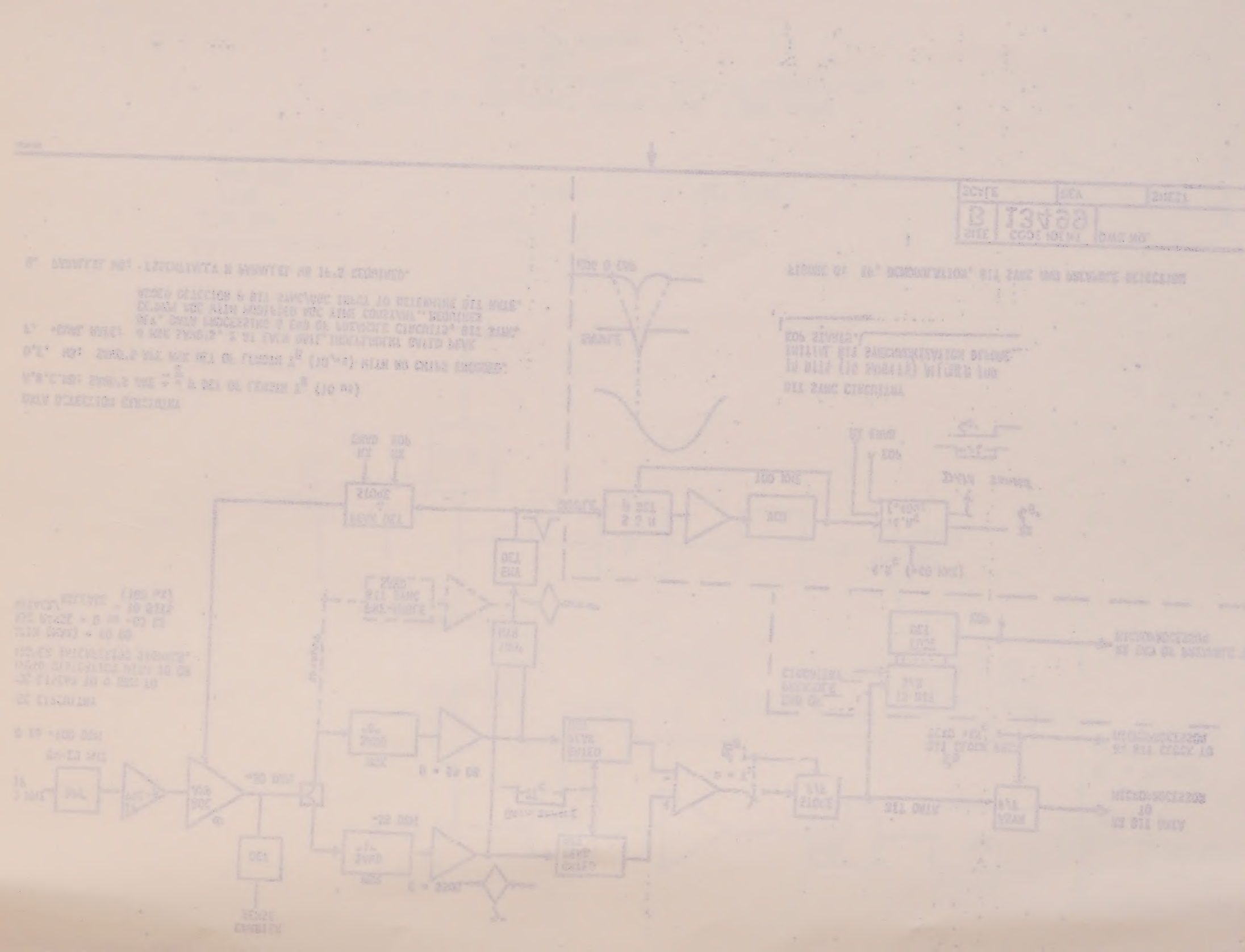


FIGURE 6: IF, DEMODULATION, BIT SYNC AND PREAMBLE DETECTION

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